UCLA
UCLA Previously Published Works

Title
Guide to the Use of Design Work Study in Naval Ship Systems Design

Permalink
https://escholarship.org/uc/item/85j4z4nm

Authors
Cooper, Joel
Esch, Lynd
Sisson, William

Publication Date
1973-01-16

Copyright Information
This work is made available under the terms of a Creative Commons Attribution-NonCommercial License, availalbe at https://creativecommons.org/licenses/by-nc/4.0/

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

GUIDE TO USE OF DESIGN WORK STUDY IN NAVAL SHIP SYSTEM DESIGN

CONTRACT NO. N00600-72-C-0485
ID NO. AP1-000464

FINAL REPORT
16 JANUARY 1973

PREPARED FOR
NAVAL SHIP RESEARCH AND DEVELOPMENT COMMAND

APPROVED BY: [signature]
R. Dubois, Vice President
Litton Systems

INGALLS SHIPBUILDING
Litton 2560 Walnut Avenue, Culver City, California 90291

INGALLS SHIPBUILDING
Litton

GUIDE TO USE OF DESIGN WORK STUDY
IN NAVAL SHIP SYSTEM DESIGN

Final Report
(Contract N00600-72-C-0485)

Prepared For

Naval Ship Research and Development Command

Ingalls Shipbuilding
Litton Systems
2560 Walnut Avenue
Culver City, California

Prepared by

Joel Cooper
Lynd Esch
William Sisson

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

SECTION 1

BACKGROUND AND INTRODUCTION TO THE GUIDE

1.1 PURPOSES AND USE OF DESIGN WORK STUDY

Design Work Study (DWS) is a method of optimizing the use of human and material resources. Although generally applicable as a technique for the study of work and work improvement in any system, for the purposes of this guide, DWS is concerned specifically with the application of Design Work Study methodology in Naval Ship System Design.

1.2 USE OF THE GUIDE

This guide is not intended as instruction in DWS or as a replacement for the Design Work Study Manual which covers the basic DWS process. Rather, it is assumed that the analyst or designer using the guide will have been previously qualified in DWS through either a Navy DWS course, a Navy-approved contractor DWS course, or sufficient on-the-job training under the supervision of personnel who have been qualified.

For users who do not have the Design Work Study Manual at hand, a brief summary of the basic DWS process is provided in Section 1.

In Section 2 the steps and techniques of DWS are repeated with cross reference to utilization in the ship design process. Additionally in this Section, the DWS techniques are discussed again in terms of reference to the Defense Systems Acquisition Process as described in SECNAVINST 5000.1. It is therefore possible to approach DWS application either from the standpoint of program development phases or from the point of view of DWS processes and techniques. Section 3 provides information on DWS working group organization.

1.3 DWS TECHNIQUES IN THE DESIGN PROCESS

The DWS process consists of a series of eight logically sequenced steps required to ensure a systematic and complete study of a problem. The process can be applied to problems at any level of detail in the system or ship design process.

1.3.1 DWS Step Summary

- Select: Within the mission/task/function hierachy, determine the stage or level of possible problem areas. Select the problem area(s) that provide the best "pay off" possibilities.

- Record: Systematically gather and record the facts from similar existing systems or design concepts using charts, diagrams and other appropriate recording tools. The success or failure of the study will hinge on how accurately and completely the pertinent facts are collected and recorded. Interviews will assist in obtaining initial information concerning Who, What, When, Where, and How.

- Examine: Critically examine the recorded facts in proper sequence to answer the question: Why? A correct reasoned answer to "Why" will establish the validity of the need for the function or system.

- Innovate: The ideation phase of the study is used to provide a range of alternatives. Ignore the constraints of the study and produce as many alternatives as possible. Use individual and group brainstorming techniques. Do not evaluate until the next step. Record all ideas but do not judge in this step.

- Evaluate: Establish objective, valid, inclusive criteria. Review the objective of the study. Analyze the alternatives according to general application. Select the alternatives which promise the most fruitful application and bring the constraints back into the study. Judge the alternatives from both immediate and long term application. Use consultants to make technical evaluation if the necessary talent is not available. Select the optimum alternative(s).

- Develop: Describe the improved function or system in detail. Prepare proposal for installation of improved system or function.

- Install: Execute the proposal as approved by management. If appropriate, test the new method on a small scale making modifications and personnel adjustments as necessary. Development of a training program may be required. Report to management when the new system is operating smoothly.

- Maintain: Follow up with periodic checks to obtain validating data, work measurement samples, production reports and maintenance information. Report progress or problems to management.

1.3.2 Documentation, Recording Techniques and Forms

The bibliography lists the applicable documentation and recording forms. For complete coverage and development of uniform study documentation, these recording forms should be used as described in the Technical Manual for Design Work Study. The listed NAVSEC forms include System Sequence Diagrams (OSD), critical examination sheets, design work sheet, manning chart, and manning examination chart. Other chart representations such as the correlation charts should be developed in accordance with DWS Manual guidance to fit each specific study.

SECTION 2

DWS IN THE SHIP ACQUISITION PROCESS

2.1 DWS METHODOLOGY AS IT APPLIES TO THE SHIP DESIGN PROCESS

2.1.1 Select

System design starts from a set of system requirements. The requirements for each design will differ depending on the mission, but in general the specified requirement parameters will be similar. For example, all ships will have requirements for speed, endurance, etc., but each class will have a specific speed and endurance requirement (e.g., one destroyer may be required to meet a 25 kn speed while another may demand 30 kn).

The following list provides a typical set of requirements representative of early specifications for a ship design.

- Speed
- Endurance
- Displacement
  - Weights
  - Moment
- Availability
  - Reliability
  - Maintainability
    - Accessibility
- Combat Capability
  - Weapons Capability
  - Sensor Capability
  - Reaction Time
  - Adjacency
  - Area Accessibility
  - Acoustical Signature
  - IR Signature
  - Topside Arrangements
  - Aircraft Handling

Survivability

- Structure
- Vibration
- Vulnerability
- Seakeeping Ability
- Damage Control

Maneuverability

- Controllability
- Stability
- Trim
- Mobility
- Turning Radius
- Collision Avoidance

Habitability

- Vibration
- Safety
- Airborne Noise
- Crew Comfort

Supportability

- Interchangeability
- Dry Docking
- Overhaul
- Spares
- UNREP-VERTREP-CONREP

Producibility

- Conversion Features
- Modernization Provisions

Manning

- Human Factors Engineering
- Outfitting and Furnishing
- Training

Anchoring/Mooring

Fleet Operations

- Intercompatibility
- Helicopter Compatibility
- Communication

Cryptographic Communication
Sonobuoy Compatibility
Technical Evaluation Mission

Cost

Acquisition
Operating

Given a set of ship project requirements, such as the above, the first task of the DWS analyst is identification of all problem areas for further analysis. It is generally advantageous to organize program requirements in graphic form showing the dependencies and relationships of the requirement elements. This can be accomplished by application of stage identification techniques. Early stage identification diagrams may indicate areas where expansion of requirements definitions are necessary or where overlapping or conflicting requirements create problems that should be identified for study.

When the requirements have been organized in relation to each other, each individual element must be reviewed to identify indications of potential problems such as heavy man-hour requirements, high cost, high skills requirements, low reliability or availability, safety problems or poor effectiveness.

Each problem identified must be described as completely as possible in terms of criteria that indicate the payoff potential associated with DWS analysis. Payoff criteria such as cost, personnel skills requirements, high technical risk, etc., should be specified, quantified, and weighted in accordance with the specific objectives of the program under consideration. For example, in a developmental program with priorities and parameters oriented to establishing a new or unique weapons capability, problems identified in the weapons elements would receive differential weighting emphasis.

When problems have been identified and evaluated, they are then arranged in order of associated payoff potential. Based on availability of funds or other constraints, the selection process is completed.

2.1.2 Record

The objective of the Record step in DWS is to obtain and retain a complete and factual set of data in useable form. Each problem or study area selected must be factually described to the fullest extent possible. In on-going ship design programs the data recorded should also be consistantly dated so that later users will be able to establish the configuration context in which the data was recorded. All drawing references; source document data; references to mockups or models; or even analytical assumptions required in early studies should be specifically spelled out.

The DWS charting techniques are very useful methods of design problem recording and analysis. Early development of general system functional flow diagrams supplemented by lower level Functional Sequence Diagrams (FSD's) oriented to specific problem areas is particularly important in obtaining clear study definition and direction.

Once FSD's have been charted there are many techniques available for examining specific elements of the system. The methods of generating charts and the approach to application of charting techniques as aids in problem definition and solution are described in NAVSHIPS 0900-005-1010-02, Manual for Work Study Technology. Techniques particularly useful at this stage include Flow Process Charts (FPC's), Outline Process Charts (OPC's), Multiple Activity Charts (MAC's), Operational Sequence Diagrams (OSD's), and other types of charts.

When prior systems using the same, or similar tasks and equipment are available, realistic observational data should be obtained. However, lack of such precedent data does not preclude effective application of DWS recording techniques. In application of the charting techniques during design, the DWS analyst will frequently be confronted with a need to chart tasks and interactions that do not exist in suitable form in prior systems. However, by interview of design personnel; analysis of drawings and performance data; and full use of DWS techniques such as Standard Time and Motion techniques, it is possible to develop detailed and reasonably accurate OSD's and other charts for tasks associated with equipment that is still under design. In fact, comparative analysis of separate OSD's reflecting design alternatives is an effective design decision tool.

All data gathered must be systematically recorded on formal data sheets. This preserves full visibility of the technical sources on which flow charts and other analyses are based. Interviews with design personnel should also be recorded in the same manner as interviews with using personnel.

Use of statistical methods during design activities involves analysis and application of system analysis and mission analysis data as well as use of obvious statistical information available from reliability models and availability analyses. Factors such as repair task frequency can frequently be estimated with satisfactory accuracy from system life cycle profiles combined with component failure rates. A similar approach can be used for operational tasks when scenarios are combined with life cycle profiles of time in various operational modes. Development of such frequency statistics is essential in ensuring proper ship arrangement and ship space layouts. It is also important in establishing design priorities for conflicting accessibility demands. Again, where comparable ships, equipment, or spaces are in current operation, observational development of statistics is preferred. However, lack of observational data does not preclude development of well founded frequency estimates and application of correlation charts or other DWS statistical techniques to design problems.

2.1.3 Examine

The Examine step in DWS is basically a logically sequenced questioning of the design data. To ensure complete and appropriately sequenced accomplishment of this step Critical Examination (CE) sheets are used to structure the process and provide a formal record of the procedure.

The CE sheet uses the information gathered in the record stage and forces the analyst to organize the information in a form which, when properly used, will yield the best alternative(s). The CE sheets lay out the problem in a way which allows for dissection. The analyst(s) must follow the DWS steps of examining at the highest system level and questioning each decision as to first, the necessity of the step; second, the timing; third, the place; and fourth, the manner. As the same techniques of examination are used at succeeding lower levels, the total problem area will be critically reviewed to yield the best solution(s).

In order to arrive at a solution it is necessary to make trade-offs between alternatives. Two factors are present in making tradeoffs; the determination of viable alternatives and the selection between alternatives. The determination of alternatives is based on experience, research and brainstorming techniques and is considered in the Innovate step. The selection of the best alternative is developed in the Evaluate step.

Although the CE sheet is universal in application it may be impossible, because of time and cost, to examine each system element by this technique. Decisions on some of the less important or lower cost elements may be based on techniques such as time line analysis, critical element analysis, task criticality analysis, or link analysis where a less time consuming and less expensive solution is appropriate.

2.1.4 Innovate

The determination of possible alternatives is a creative undertaking. Too often a new design is merely a repeat of previous design. While there is merit in using past experience and data to avoid reinventing, a creative approach will often provide a more effective or lower cost solution.

Innovative or creative design approaches are best developed in a permissive or non-critical environment. DWS provides a separate process step for this purpose. Where appropriate, the brainstorming technique described in NAVSHIPS 0900-005-1010-02 should be utilized. Group participation in this process will undoubtedly produce the greatest number of potential design alternatives in the shortest period of time.

Depending on the size of the program and practical work constraints, group brainstorming may not be applied at all levels of the design process. It is important to ensure that innovative approaches based on research in technical literature, reference to existing systems or ingenious transfer of principles from other design contexts are also recognized and recorded on the CE sheet so that they are accorded an appropriate evaluation.

2.1.5 Evaluate

The total array of alternate ideas recorded in a brainstorming session is screened to eliminate obvious misfits that are an expected part of this process. The remaining approaches are then recorded in the appropriate section of the Innovate column of CE Sheet I and developed in more detail to support the Evaluate step.

Evaluation in Design Work Study is the process of selecting between alternatives. In this process it is first necessary to set the criteria against which the alternatives will be weighed. Next the weighting factors or methods are determined and after this the evaluation is performed.

The major criteria for evaluation are cost, time and performance. Initially, any alternative not meeting these three major criteria can be eliminated from consideration thus limiting the alternatives to be evaluated.

There is a second set of criteria which becomes paramount once the initial limitation has been made. These criteria are dependent on the project or study objectives. Assuming all the alternatives that have not been weeded out can satisfy the system requirements, the project can then be examined to determine the key criterion. For example, if the key criterion is least cost, the alternatives which are not relatively low cost equal can be eliminated. Decisions between low cost alternatives can then be made based on the next lower level criterion. This method lowers the alternative spectrum consequently reducing the amount of decision time and effort.

On the other hand, more often than not there is more than one criterion. The evaluation then must be made on one of several evaluation techniques. In these cases, the selection of a decision must be made as to the relative weight of each criterion, and the factors assigned either ordinal or cardinal numbers. The sum of individual weights times number will then yield a ranking of the "best" alternatives.

The detailed criteria and weighting calculations applied to all alternates should be recorded on DWS worksheets. The summary of this data and the rationale for selection are recorded in the Evaluate column of CE Sheet I.

2.1.6 Develop

In completing the Develop step of the DWS process, the analyst defines the technical tasks, sequence of work, and appropriate organizational support required to accomplish design implementation of alternates selected by the critical examination process. In preparing development data for the CE sheet the analyst should consult program organization and planning documentation to ensure that recommended developments are compatible with other program elements. Development timing should fit with program PERT networks. Interfacing designs and organizations should be identified and informed. Recommended design assignments should fit with program organization structure and budgets.

Thorough and compatible plan development can be as critical to design as the technical adequacy of the selected alternate.

2.1.7 Install and Maintain

The installation concept of DWS refers to generation of the overall plan for implementation of a design feature in a system. This phase includes specification of personnel and training requirements, time phasing of equipment deliveries and preparation for practice on trial runs with new installations.

"Maintain" refers to periodic observation of the new installation to ensure that it continues to operate as designed.

In design of new ships the Install and Maintain steps of work study are basically accomplished at one time for the whole ship as a part of prototype fabrication and test and evaluation activities. The role of DWS in these phases is primarily monitoring and examination of design changes for total system impact and necessary modification to the original concept.

2.2 SHIP ACQUISITION PROCESS

Naval Ship Systems are conceived, developed and produced in accordance with the defense systems acquisition process as defined in SECNAVINST 5000.1. Basically, this process involves an iterative series of design and evaluation activities that progress from general ship concepts to the completed ship. And finally includes a test and evaluation stage where design objectives are compared with actual performance.

For a complete and authoritative description of the naval ship acquisition process reference should be made to SECNAVINST 5000.1. The following summary is provided for quick reference to those aspects of the process that particularly impact on direct design activities including DWS analysis.

The Chief of Naval Operations (CNO) and the Commandant of the Marine Corps (CMC) identify operational needs, determine characteristics and define requirements to meet their needs. Together with civilian executive assistants, the CNO and CMC advise the Secretary of the Navy on decisions relative to initiation and attachment of major acquisition programs.

The procedure for the program of any major acquisition is divided into three phases, Program Initiation (PI), Full-scale Development and Production/ Deployment.

2.2.1 Program Initiation (PI) Phase

In the PI phase the responsible DOD component directs the conceptual effort until such time that a determination is made that a major defense system program should be pursued. The determination of the need for the program along with the program plan is documented in a Development Concept Paper (DCP). The DCP defines program issues, including special logistics problems, program objectives, program plans, performance parameters, areas of major risk, system alternatives and acquisition strategy.

Engineering and design activities during the PI phase are generally conceptual in nature and deal with ships or subsystems that may be defined only in general terms with performance requirements constrained to bands but not finally fixed. A relatively large number of system or subsystem alternatives may be under consideration at any one time and if the ship system under consideration includes major technological advances, there may be relatively sparse precedent data available to the DWS analyst. However, DWS analysts are required to establish the manning baseline for the system early in the PI phase, and DWS analyses of critical early conceptual problems provide a source of systematic and objective data that can heavily influence all subsequent stages in ship definition and development.

When the conceptual effort has been conducted to the extent that the CNO or CMC feels that the program should be pursued and the Office of the Secretary of Defense (OSD) approval will be required, the program status is reviewed by the CNO Executive Board (CEB) and/or CMC where appropriate. Appropriate recommendation is then made to the Secretary of the Navy prior to Defense System Acquisition Review Council (DSARC) presentation. The position taken is reflected in the DCP. If DSARC approves, the program is sent to the SECDEF for subsequent decision. If approved by the SECDEF, the program is conducted within the DCP thresholds.

Design activities in the validation period that occurs after an approved program has been defined can vary over a great range. Work at this point may involve a complete design cycle with prototype fabrication and evaluation. In other cases design activities may focus on a limited number of high risk subsystems and components. DWS analyses can range from conceptual investigations to nearly traditional work study problems with well defined precedent data. In all cases the DWS activity must take the stage of engineering development and required study scope into account in selecting and applying DWS techniques. When the DOD component is sufficiently confident that program worth and readiness warrant commitment of resources to full-scale development, it will request a SECDEF decision to proceed. DSARC will review program progress and suitability of the program to enter full-scale development and forward its recommendations to SECDEF for final decision.

2.2.2 Full Scale Development

When a ship system enters full scale development, ship and subsystem definition will have progress to a point where requirements are firm and more comprehensive than in earlier phases. The overall design process starts from these requirements and proceeds through prototype or lead ship fabrication followed by test and evaluation. During this effort, a preliminary ship manning document is developed and hardware requirements and procedures become concrete so that data from precedent ships or similar systems is more readily available for DWS analytical purposes. It is during this phase that DWS design techniques are most widely applicable and can have the greatest impact on the cost and performance of the ship.

When the DOD component is satisfied that engineering is complete and that the commitment of substantial resources to production and deployment is warranted, it will request a SECDEF decision to proceed. Here again DSARC will review and forward its recommendations to SECDEF for final decision.

2.2.3 Production/Deployment

During the production/deployment phase, design engineering activities are usually constrained to ship improvement, modernization or modification efforts of limited scope. However, these efforts can have major impact on the utility and effectiveness of fleet units. Since operational units are, during this time period, deployed in increasing numbers, DWS can play a significant role in design activities conducted at this time.

2.3 DWS AS RELATED TO SHIP ACQUISITION

The application of the DWS discipline in the ship acquisition process can be expected to vary considerably from program to program. As SECNAVINST 5000.1 indicates, each program has differing requirements and the design and program plans are adjusted to support these requirements. However, DWS provides suitable methodology for dealing with studies of varying scope and content in all phases of the ship acquisition process.

2.3.1 DWS in Program Initiation (PI)

The PI phase of the acquisition process includes a conceptual sub-phase and a validation sub-phase. Conceptual studies, by necessity, cover a wide range of content and are conducted at levels of detail that are selected to support concept development. For purposes of orderly discussion these studies will be categorized as Research and Development (R&D), Concept Definition (CD), and Concept Validation (CV) studies.

2.3.1.1 Research and Development (R&D)

Although R&D is extremely broad in scope, individual R&D activities are generally characterized by relatively narrow or specialized technical scope and concentration on a detailed level of engineering or scientific content. Since DWS steps basically follow the scientific method of problem definition, postulation of solutions and evaluation of solutions, it is readily adaptable to R&D efforts. Initial DWS steps of Select, Record, and Examine, may be used to deal with functional characteristics of sensors and prime movers, or even with attributes of individual parts. At this level much of the data involved in the Record or Examine steps will be derived from scientific or engineering journals. The examine step together with the Innovate step that follows will often yield resulting concepts that will require laboratory or field experimentation to generate the data required to accomplish evaluation. A major practical contribution of DWS to R&D efforts is that it provides a method of using data from prior systems to generate evaluation criteria that ensure a real world orientation of selected R&D solutions.

2.3.1.2 Concept Definition (CD)

Conceptual efforts characteristically deal with variable or partially defined functional approaches to system, subsystem, or lower level problems. Again the application of the DWS process assists in ordering data, generating arrays of alternate conceptual approaches, and evaluating and selecting the most suitable concepts for further development and design effort.

At this level of concern, the stage identification is usually entirely functional, and the Record and Examine steps are concerned with definition and adequacy of functions and concepts in providing full coverage of the cause and need requirements of the conceptual problem under consideration. The analyst must adjust techniques to deal with value ranges rather than fixed requirements. Selected concepts normally retain considerable flexibility and require extensive subsequent development before the design requirement level of definition is achieved.

2.3.1.3 Concept Validation

Typical concept validation efforts are directed toward refining concepts to the level of definition necessary to formulate design requirements. Such efforts may also involve fabrication of prototype elements and sufficient test operations to validate and definitize certain aspects of prior conceptual efforts, or reduce risk levels associated with the overall program concept. For example, prior conceptual studies may have indicated that required cruise speed for a ship was in the 25-30 kn range. The concept validation study would be oriented toward definition of the minimum cruise speed to be called out as a requirement for the ship in full scale development.

2.3.2 Full Scale Development

The full scale development phase includes system design, detail design, prototype fabrication, and test and evaluation efforts. The DWS discipline has a significant role in each of these efforts. Major events of full scale development are indicated in Figure 2-1.

2.3.2.1 System Design

The System Design effort is initiated at the beginning of full scale development and starts from a specified requirements baseline established by PI efforts. The general and top level functional analyses are complete, and in certain areas specific hardware elements may have been identified by PI studies. DWS analytical data from PI efforts are assumed to be available as a DWS baseline.

During system design an extensive engineering effort is required to develop system, subsystem, functional element, and long lead procurement specifications. Drawings and calculations must cover all ship elements to a level of detail sufficient for system design review. Planning for procurement, prototype fabrication and production must parallel design development.

The DWS effort in system design is initiated with a review of requirements and prior DWS documentation to ensure that late baseline changes are fully reflected in FSD's and other baseline record data. After baseline data is verified or updated, as required, the DWS process is reinitiated at the design level of detail. Requirements are subjected to the Select process. Selected problem areas are defined in detail by the Record process, and recorded data is entered into the Critical Examination process that should coincide with and support all major system design trade-off studies.

OSD's, which would apply only to problem areas during PI, are now expanded to cover all shipboard operational tasks. Operational task data in OSD format is developed in parallel with equipment and ship design data to support preliminary operational stations book issues and to provide adjacency criteria for development of ship space arrangements. OSD coverage is best ensured by development of a ship coverage matrix listing all ship compartments on one axis and all operational modes on the other axis. Cells in the matrix would include lists of operational sequences occurring in each space in each mode of operation. When all operational sequences for all spaces and conditions have been diagrammed, OSD analysis coverage is complete. Orientation of OSD's by ship compartment has the further advantage of providing OSD Input and Output columns that can be checked to ensure adequacy of communications system design and proper availability of specific IC circuits in each space where they are required to support operational tasks. The major impact of overall OSD coverage is on ship space layouts since a summary correlation chart of all OSD's for a given space provides quantified adjacency requirements data. Correlation data from detailed OSD's provides an operationally based and quantified basis for layout development not available in other systems or engineering analytical activities. Summary correlation

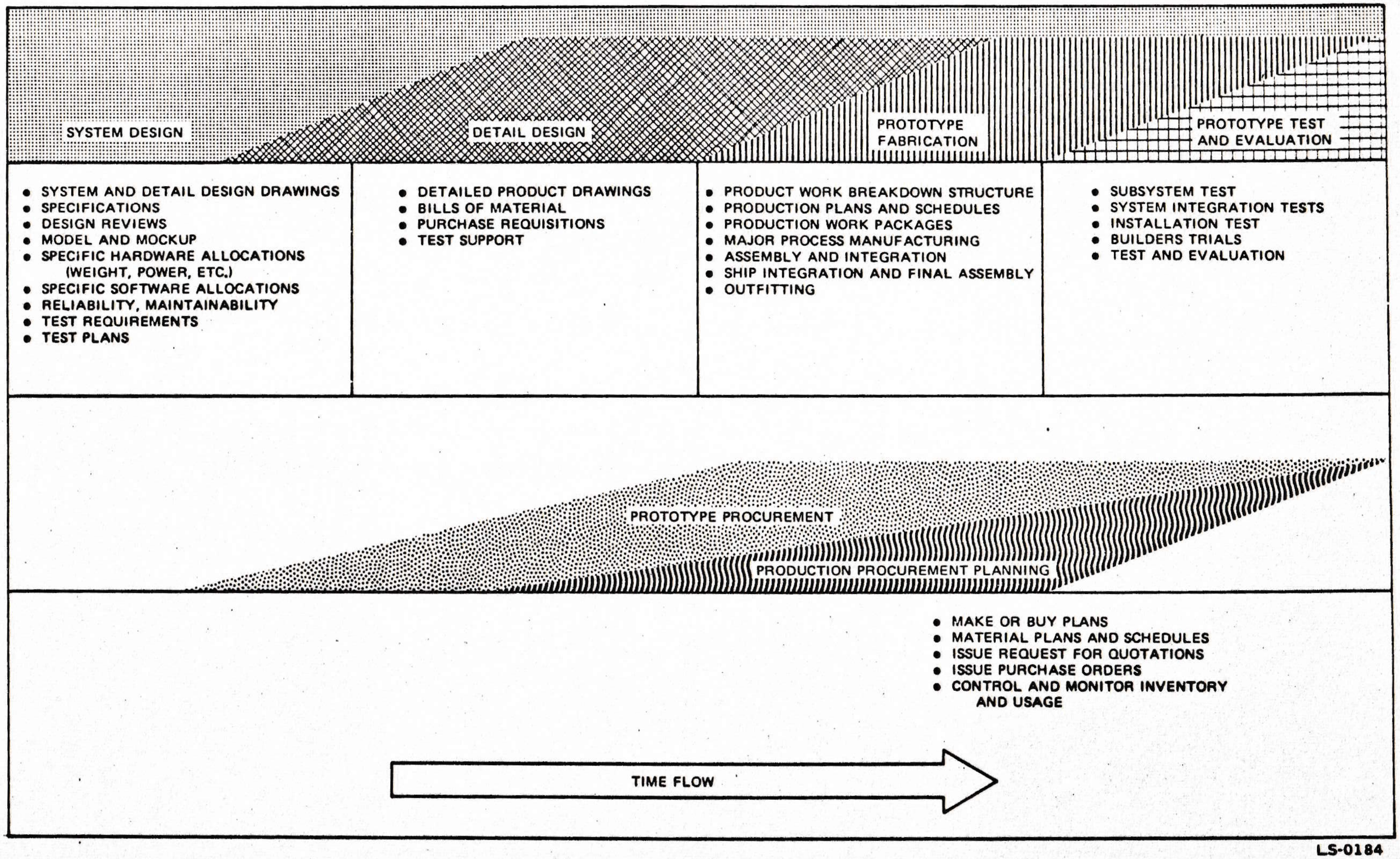


Figure 2-1 Full Scale Development Process

data may be made more effective in some cases by applying weighting based on life cycle frequency data or mission criticality data depending on the particular space in question.

OSD's must be updated and expanded as design data becomes more detailed. Correlation chart data and adjacency requirements must be updated in parallel with this effort to ensure that ship compartment layout criteria are kept current. Final OSD's are a direct input to the Operational Stations book and provide a basis for defining operational manning requirements.

Due to the volume of OSD's generated by the design development process and the continuing requirement for OSD updates and changes, computer based charting and correlation techniques should be seriously considered for any major ship development effort. Manual modification and correlation techniques introduce considerable time lag and many even prevent timely support of design decisions on tightly scheduled programs.

For combatant ship design there is one category of task/equipment operations that is by definition, critical, and requires special DWS emphasis. This category includes the necessary events that occur between sensor detection of a threat and firing or launch of the ship weapon committed against that threat. The minimum time span required for these events under worst case engagement geometry situations is designated as reaction time (RT). Each sensor/weapon chain in a ship will have one or more RT's. Out of a total set of ship RT's, certain defensive RT's will be essential to ship survival in a combat environment and other offensive RT's will have major impact on combat effectiveness. DWS is particularly effective in the analysis and optimization of RT's. Once the total set of sensor/weapon chains has been identified and ranked in order of criticality, the Record step techniques are applied at a very detailed level. Particularly applicable techniques include multiple activity charts, RT oriented OSD's with precise time base, PERT type networks, or custom designed RT networks. Computer based techniques are desirable due to frequency of use.

RT's normally are more than 95 percent personnel task time with governing sequences constrained by a series of single operator tasks. Significant RT payoff is heavily dependent on successful DWS effort.

As individual DWS studies are completed during system design it is highly important that the characteristics of developed solutions be reflected in the drawings and specifications that define the ship configuration. Each completed study should specifically identify the drawings and specifications affected. Specification data developed by DWS should be converted to appropriate language and organized to coincide with standard military specification section and paragraph structure for the element or equipment in question.

Proper implementation of DWS recommendations should be confirmed by DWS participation in design and specification review processes.

The Install and Maintain steps of DWS are represented during System Design primarily by development of plans for subsequent design, development and test efforts. For example, if DWS study results in requirements included in a particular functional element specification, DWS should work in parallel with design to identify specific equipment items impacted by the functional element requirements. Any lower level studies anticipated during detailed design should be identified and included in planning for that time period. Test and Evaluation monitoring necessary for final validation of DWS should also be identified and included in planning. At the completion of System Design the DWS activity will have completed all schedule studies, developed specific ship system design requirements, and prepared a plan for DWS participation in detailed design. A summary of DWS activities in systems design is provided in Figure 2-2.

2.3.2.2 Detail Design

The detail design sub-phase of Full Scale Development includes all engineering activity required to convert ship system drawings and specifications into detailed design drawings and procurement specifications suitable for use in ship prototype fabrication. In addition, the planning and preparation for procurement, prototype, fabrication, prototype test and evaluation, and production/deployment actions must be accomplished to the extent required to support the overall program schedule.

During Detail Design DWS participation continues from the baseline and plan established during system design. The sequence of effort and DWS techniques employed are basically the same as in system design. The major difference is the level of design concern. Whereas the Select process initiated at the beginning of system design was addressed to a list of requirements, this effort is now directed to the approved system design which is fully structured and has extensive engineering definition. Critical examination and trade-offs are now predominantly aimed at specific hardware design or selection. OSD analyses are refined in parallel with hardware decisions to support timely production of personnel planning data, training course data, and the final Operational Stations Book to be used by the ships crew during prototype evaluation efforts.

As engineering shifts to a more detailed level of ship definition, DWS studies also concentrate on lower level, more detailed, problems. This shift in emphasis requires some change in the frequency with which certain DWS techniques are applied. When mockups are available, time and motion techniques of work study can be applied to simulated task performance to validate or revise early estimates. Individual operator control arrangements can be analyzed by right hand/left hand diagrams and link analysis combined with correlation charts. Higher level analyses, such as FSD's, are updated during this phase, but the frequency and extent of change at upper levels declines. DWS critical examinations will define items such as detailed display and control placement requirements at specific operator stations. Specification requirements will be largely at the equipment procurement specification level.

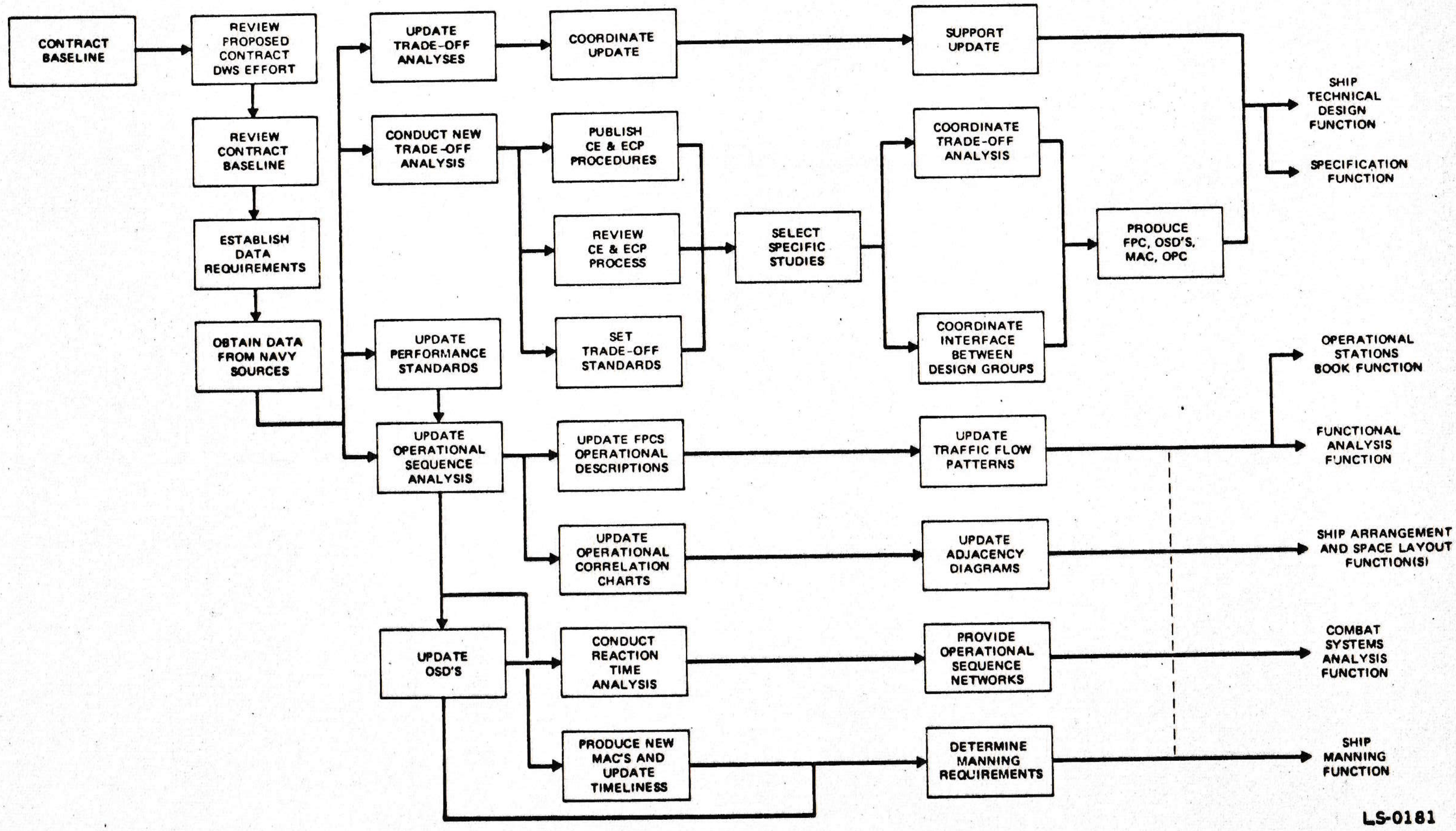


Figure 2-2 DWS Responsibilities in System Design Phase

During detail design, the ship design progresses from a system design baseline to a fabrication or production baseline and design configuration control becomes more formal and more complex. DWS participates in the design review process to ensure that detail design considerations are not allowed to invalidate earlier design recommendations. For example, if DWS studies have established passageway width requirements to accommodate anticipated crew movement patterns, considerable review vigilance will be required during detailed design to ensure that passageway integrity is not impaired by placement of "oversight" equipment in critical passageway locations. Maintenance access requirements also require nearly continuous review.

Engineering Change Proposals (ECP's) are a major source of new DWS studies in the detailed design period. These may come as the result of new technological advances; be generated by new or additional ship mission requirements; or result from the need to resolve design problems that were not apparent until detailed implementation was attempted. In any case DWS activity should review ECP's for their relationship to earlier studies and requirements and, particularly in complex changes, subject the ECP elements to the Select process to determine if DWS study offers a significant payoff potential during change implementation. Where payoff value warrants, DWS study should be incorporated as a part of the required ECP action plan.

In parallel with the design studies and design review and monitoring efforts noted above, DWS plans for test and evaluation efforts are defined during detailed design as specific task and hardware data is established. DWS Test and Evaluation (T&E) plans should be closely coordinated with formal Test and Evaluation plans to ensure that DWS observers are scheduled for engineering test, trials, and T&E evolutions that are suitable for accomplishing the Install and Maintain objectives of the discipline.

2.3.2.3 Prototype Fabrication

During prototype fabrication the DWS role is primarily one of monitoring ECP's and reviewing design modifications by manufacturing engineers to ensure that the integrity of the detailed design is accomplished by the "as built" hardware. DWS techniques employed are essentially identical to those utilized in detailed design.

2.3.2.4 Evaluation and Test

The DWS group will essentially support and partially monitor those elements of the system in which they have played a design role during the Evaluation and Test program.

2.3.2.4.1 Hardware Elements

Fundamentally, the test plan for hardware elements will demonstrate the satisfaction of the specifications which have been generated by the various design functions. Based on the test plan the role of the DWS group will be to monitor the sequence of operations and the operational procedures for elements such as the following:

a. Propulsion

b. Armament

- Missile Element
- Gun Element
- ASW Launching System
- Miscellaneous Ordnance

c. Auxiliary

- Strikedown System
- Helicopter for Aircraft Handling Systems
- Mooring Towing System
- Underway Replenishment (UNREP) Overside Handling System

d. Command and Control

- Non-Electronic Navigation System
- Ship Control System
- Interior Communication System
- Information Acquisition and Display
- Underwater Surveillance and Communication
- Damage Control System
- Electronic Navigation System
- Gunfire Control System
- Guided Missile Fire Control System
- Underwater Radar and AIMS System
- Command and Decision System
- Radio Communication System

e. Outfit and Furnishings

- Commissary System
- Boat Handling System
- Medical Spaces
- Utility Spaces
- Office Spaces
- Workshops, Laboratories, and Test Areas

2.3.2.4.2 Non-Hardware Elements

Many non-hardware aspects of test and evaluation involve personnel oriented evaluations in which the Human Factors organization has prime responsibility.

However, DWS can frequently assist or support Human Factors in these efforts. Typical non-hardware tasks of this type are as follows:

a. Hull

Verify that adequate space and environmental conditions are provided for interactions between crew personnel and hull-equipment. Ensure that there are provisions to assist critical human task performance throughout the full range of hull motions.

b. Propulsion

Verify that controls and displays are integrated for operating, monitoring, and maintaining system equipment. Ascertain that system functions are appropriately allocated to personnel and equipment. Verify the comprehensive operating and emergency procedures that have been developed. Verify that the system environment is within the tolerance of anticipated crew members.

c. Electrical Subsystems

Verify major Human Factors objectives only; System Safety organization has key effort with which Human Factors will cooperate.

d. Command and Control

Verify that the optimum combination of electronic capability (speed and accuracy) and human judgment (experience and flexibility) has been established to ensure appropriate tactical responses. Ensure that the flow, transformation, and transmission of surveillance information, navigation information and communications information on the part of ship personnel has been optimized. Ascertain that workspace has been designed to optimize the interactions among personnel in command rooms and in ship control areas.

e. Auxiliary Subsystems

Verify that equipment and procedures are designed to aid performance of vital human tasks in helicopter support, in replenishment at sea, and in steering, anchoring, and mooring/towing. Ensure that provisions have been made for maintaining suitable environmental conditions for the ship personnel. Verify that emergency equipment has been provided for occasions when environmental parameters are forced to levels beyond normal tolerance of the ship personnel.

f. Outfit and Furnishings

Verify that the dimensions and design of nonstructural bulkheads and doors provide free passage of personnel in the 5th through 95th percentiles in size measurements. Ascertain that antiskid surface coatings are provided in passageways and living and working spaces as necessary to prevent slips and falls. Verify that all living, messing, and recreational spaces meet the Navy habitability requirements.

g. Armament

Verify that equipment and procedures are designed to aid performance of vital human tasks in operation and maintenance during ammunition handling, during weapons aiming and firing, whenever necessary for counteracting malfunctions and misfires, and during all armament subsystem emergency situations. Ascertain that adequate spatial allowances have been made to assure performance in armament workspaces and duty positions. Verify that equipment items which must be lifted or moved do not exceed the maximum weight tolerable by the men or man-machine combinations designated to do the lifting or moving.

Specifically, whenever the DWS group has been reasponsible or instrumental in developing procedures, trade-offs, operational sequences or adjacencies, it will have the responsibility of providing inputs in these areas to the test procedures and monitor and report the test results. Providing that DWS inputs to Section 4 of System and Subsystem specifications has been sufficiently detailed, test procedure inputs are readily generated. In the event that the test results indicate an inability to meet performance requirements, the DWS group will be required to revise and retest the procedural elements in these areas.

Other non-hardware elements are considered in more general test areas. Typical elements of this type include the following:

a. Operational Stations Book
b. Ships Manning Document
c. Training
d. Maintenance
e. Reaction Time
f. Human Factors

Depending on the organizational responsibility as specified by the individual program organization, some of these elements may or may not fall within the purview of the DWS group. Whether or not they do, the test requirements are the same. However, the DWS group will normally have the prime responsibility for the test plan, execution and reporting for the Operational Stations Book and the Ships Manning Document. Test results must be recorded and analyzed in a manner which assures both a feedback of information for use on the program under consideration and a base for other ship programs.

It is important to make efficient use of test running time by combining test operations where possible. It is also essential that all test plans be examined to make certain that all required test and validation areas are fully covered. To accomplish this goal the actual content of each test operation must be examined. For example, an "OSB Validation Test" normally refers to MIL-M-15071 requirements and validates the OSB as a document. Such a test does not assure that the operations described in the OSB are adequate. To get test coverage of the operational adequacy of an OSB it is usually necessary to coordinate with cognizant design functions and arrange to collect data from all of the engineering tests that validate satisfactory operation of the hardware elements covered by the OSB. The OSB function will want to determine, at least for the critical areas, which have been defined in the OSB, that the duties and responsibilities for personnel are consonant with the operation as described. Additionally, the ship manning organization will have to provide a demonstration of the efficacy for the specific areas. Further, the same tests may serve to demonstrate the meeting of Human Factors, Safety and Maintenance requirements. To avoid duplication a very careful examination will have to be made by all functions in concert. A small expansion of a specific operational test requirement may easily lead to satisfying all group test requirements in one combined test operation.

Reaction Time verification is a particularly important concern of DWS Test and Evaluation efforts. It is not usually feasible to exercise all ships systems and functions involved in all reaction times, under the precise conditions of range, worst case geometry, exact target characteristics, etc., that are described in the original performance requirements. However, it is essential that the most critical RT's be fully verified and that all other RT's are exercised under conditions close enough to original requirements to ensure that specified RT performance can be achieved under deployment conditions. Development of RT test plans requires careful analysis of all useful test operations to keep test costs in a feasible range.

For example, the time required for any in-line operator task in a reaction time network will exhibit considerable variation under fleet use conditions. A small number of runs by a single operator will not firmly validate RT accomplishment in most cases. DWS, in developing test plans, should consider the collection of RT task performance data from prior systems, shore based tests, training operations or other ongoing activities so that T&E repetitions at sea can be approached on the basis of confirming an established task time distribution rather than attempting to develop a new statistically significant sample of operator performance.

There undoubtedly will be tests which cannot be conducted simultaneously. Since the OSB contains only critical operational areas, it will not suffice as a test of the manning of commissary spaces, etc., for the Ships Manning Function. Similar lack of coverage will be found by the Human Factors, Safety, Maintenance Analysis, and Combat Systems Analysis Functions. It is therefore imperative that all of these groups input their individual test requirements to the Test and Evaluation Function in order to assure a logical and efficient overall operational test.

As the operational tests are conducted, the DWS group must exercise the Install and Maintain steps. The reporting and measuring at this stage are critical. On any particular ship, procedural changes can be developed if found necessary by the DWS group. Recommendations may also be made for specific advantageous hardware changes for production ships of the prototype class.

2.3.2.4.3 Test Planning

The elements of a test plan must describe the activities to be accomplished by the specific organization and the schedules, tasks, and organizational responsibilities necessary to carry out the activities. The test plan must identify whether the required test data will be obtained by test engineers as an integral part of scheduled tests or by cognizant personnel using direct observation or other standard measuring techniques.

The plan should be designed to accomplish the following:

a. Evaluate the design, selection and arrangement of the subsystem components to ensure maximum compliance with applicable criteria.

b. Evaluate the man-machine interfaces with the subsystem to ensure incorporation of hardware and procedures reflecting applicable principles.

c. Demonstrate that the man-equipment combinations can accomplish on-time implementation of all tasks required by the specifications (including operation, maintenance, and control tasks).

d. Provide adequate inputs, test support, analysis, and documentation to Test and Evaluation (T&E) organizations.

The cognizant non-hardware functions will have the following corollary responsibilities:

a. Verifying that the design of all ship equipment is compatible with, and properly supports personnel performance in achieving system operability, maintainability, safety, and reliability objectives.

b. Verifying that all personnel using the ship system are provided with adequate personnel support items such as: health, safety, sustenance, escape, survival, and environmental subsystems. This also includes all personnel support aspects of ship habitability.

c. Verifying that the number of personnel and the type of skills specified for the program achieve the task performance required for efficient, safe, and reliable system operation and maintenance.

d. Verifying that personnel who have completed training are capable of operating and maintaining the system, utilizing only authorized equipment and technical procedures; and that training aids and devices are effective and adequate in supporting the training program.

e. Verifying that all technical manuals, procedures, Maintenance Reqirements Cards (MRC's), and training manuals are written in a clear concise manner, in order to promote efficient use by Navy Personnel in an operational environment for either normal or emergency modes of operation.

f. Verifying that unreliable human performance, human errors, or failures are detected, identified and recorded, so that recommendations for appropriate corrective actions can be initiated to the design of equipment or writing of operating procedures.

2.3.2.4.4 Test Categories

It is evident that verification and testing must be carried on at many levels prior to the complete final operational testing. In the early stages of design, models should provide the necessary information. As design progresses, mockups and models will more closely approach the final design and information outputs will become more precise. At each stage of modeling, a defined set of test requirements within the limitations of the system development must be provided. The DWS group has the responsibility for inputting its test requirements for each test stage in addition to the overall test and evaluation for the total ship system.

SECTION 3

DESIGN ORGANIZATION ELEMENTS

3.1 DESCRIPTION OF FUNCTIONS

It is recognized that there is a wide variation between one design organization and another, in department titles, responsibilities, and reporting structure. To provide universal organizational nomenclature which would satisfy all design organizations would be impossible. However, as this guide covers DWS responsibilities, a list of functions with a description of the specific inputs and outputs for each is provided in the paragraphs that follow. The individual design organization must establish its own optimum structure for the tasks associated with each specific design program.

For the purposes of this document, it is assumed that a DWS Group will be established at some place in the program organizational structure. Without this recognition of the functions, the Group will not be budgeted and will not have the status to assure Design Work Study as an operating entity within the system. The general function of a DWS group is integration of the inputs from various functional design groups according to DWS procedures and promulgation of DWS requirements and data as outputs. The input/output relationships for the DWS functions are shown in Figure 3-1.

On most major ship programs DWS tasks are performed by both Design Agent/Contractor and Navy organizations. Paragraphs 3.2 through 3.4 refer primarily to common Design Agent/Contractor DWS functions. Paragraph 3.5 describes the current USN DWS functional organization.

3.2 DESIGN AGENT/CONTRACTOR DWS GROUP

At various stages in the ship system aquisition process contractor DWS groups perform all of the input/output functions shown in Figure 3-1. To accomplish these functions there is a basic internal flow of DWS operations imposed by the DWS process and the ship system design development sequence. Figure 3-2 shows the functional flow relationships of these DWS processes.

While the scale of operation and emphasis on individual functions and techniques will vary, the contractor DWS organization should make provision for accomplishment of all required functions by appropriately trained technical personnel. The DWS Group should be organized and authorized to accomplish the technical interfaces associated with both input sources and output recipients.

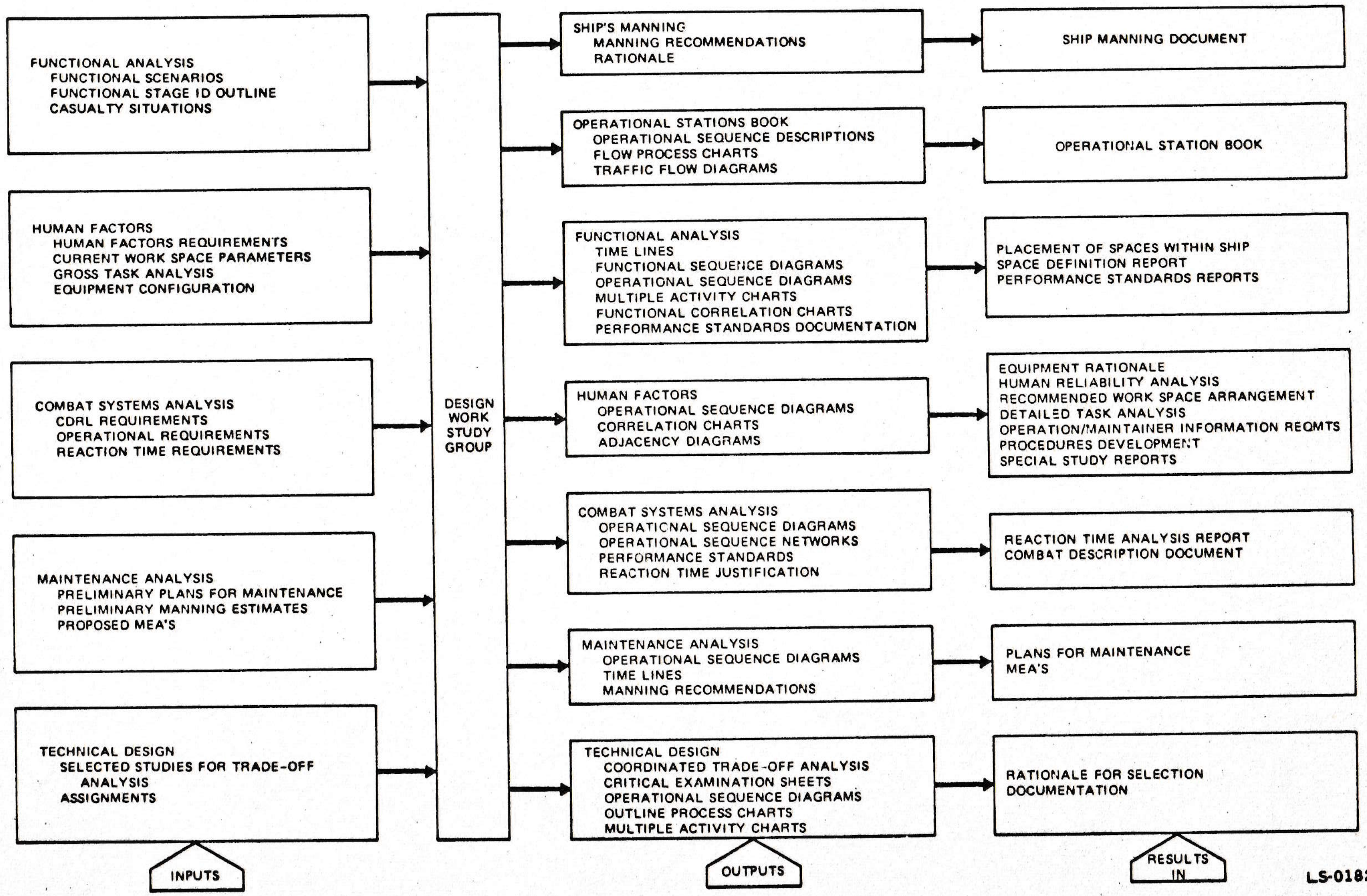


Figure 3-1 Input-Output Relationships Between DWS Functions and Other Functions

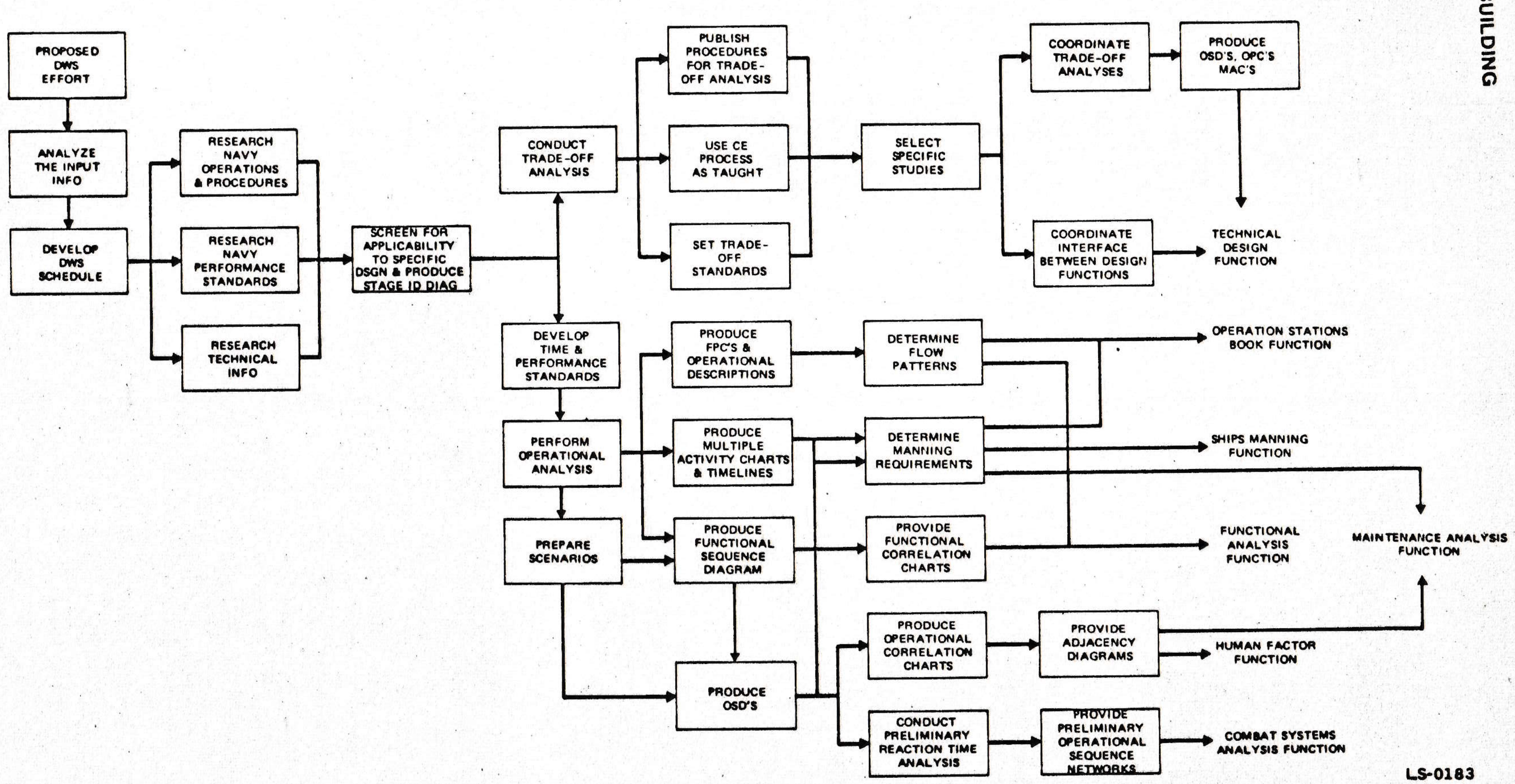


Figure 3-2 DWS Responsibilities

3.3 RELATIONSHIP OF DWS ELEMENTS TO CONTRACT DATA REQUIREMENTS LISTS (CDRL'S)

CDRL's are the contractually specified requirements that describe all technical and administrative documentation that a design agent or contractor submits to the Navy to demonstrate accomplishment of a ship design effort. While CDRL's differ from one contract to another, they include, directly or indirectly, all of the formal outputs required from the DWS process. The Design Agent/Contractor DWS Group must carefully review these requirements to assure that their tasks will produce all required outputs. CDRL's can be conveniently divided into the following general groups:

- DWS of selected areas as directed
- Administrative andFinancial
- Configuration Management
- Engineering Data Support
- Handbooks
- Logistics
- Management and Program Evaluation and Review Technique (PERT)
- Procurement and Production
- Personnel Subsystem (Training)
- Reliability/Maintainability/Availability (R/M/A)
- System/Subsystem Analysis
- Test
- Provisioning
- Maintenance

Within these areas the DWS organization will contribute direct support to the following:

- Operational Stations Book
- Ship Manning Document
- Proposed Watch Quarter and Station Bill
- Reaction Time Analysis Report
- Combat System Description Document
- Special Tests Report

In addition, the DWS Group will provide inputs to, or indirect support for the following:

Configuration Management

- Specification Change Notice (SCN)
- Engineering Change Proposal (ECP)

Handbooks

- Equipment Technical Manuals
- Ship Information Book
- Propulsion Systems Operating Guide

Logistics

- Plan for Management of Logistic Elements During the Operating Life of the Ships.

- Summary Report of Intermediate and Depot Level Support Requirements.

Personnel Subsystem (Training)

- Training Plan
- Training Course Plans
- Simulated Combat Team Training Exercise Package

System/Subsystem Analysis

- System Safety Progress Report

Maintenance

- Maintenance Index Pages (MIP's) and Associated Maintenance Requirements Cards (MRC's) and Equipment Guide Lists.

- Maintenance Engineering Analysis Records (MEA's)

- Update of PMS Documentation Package

- Plans for Maintenance (PFM's)

3.4 SHIP SYSTEM AND SUBSYSTEM SPECIFICATION RELATIONSHIP

Figure 3-3 shows the system and subsystem specifications tree for a typical modern destroyer. Beyond the subsystem specifications, shown in the figure, there are procurement specifications which become more detailed as the tree continues to branch. The first subsystem level contains the major basic DWS inputs to the specifications. Lower tier inputs are normally derived from subsystem requirements but may be developed directly out of discrete DWS studies of detailed problems.

The notation index in Figure 3-3 indicates the general types of DWS studies that typically impact subsystem specifications for a ship of this type. Each ship program will have characteristic specification trees and will show variation in the particular specifications impacted by DWS output.

DWS inputs to specifications are based on studies that include Time Lines, OSD's, MAC's, SMD inputs, adjacency diagrams, OSB material and, for most major studies, completed CE sheets. However, these documentation elements are not used directly in the specifications. The data or conclusions with specification impact must be transferred from the working analytical

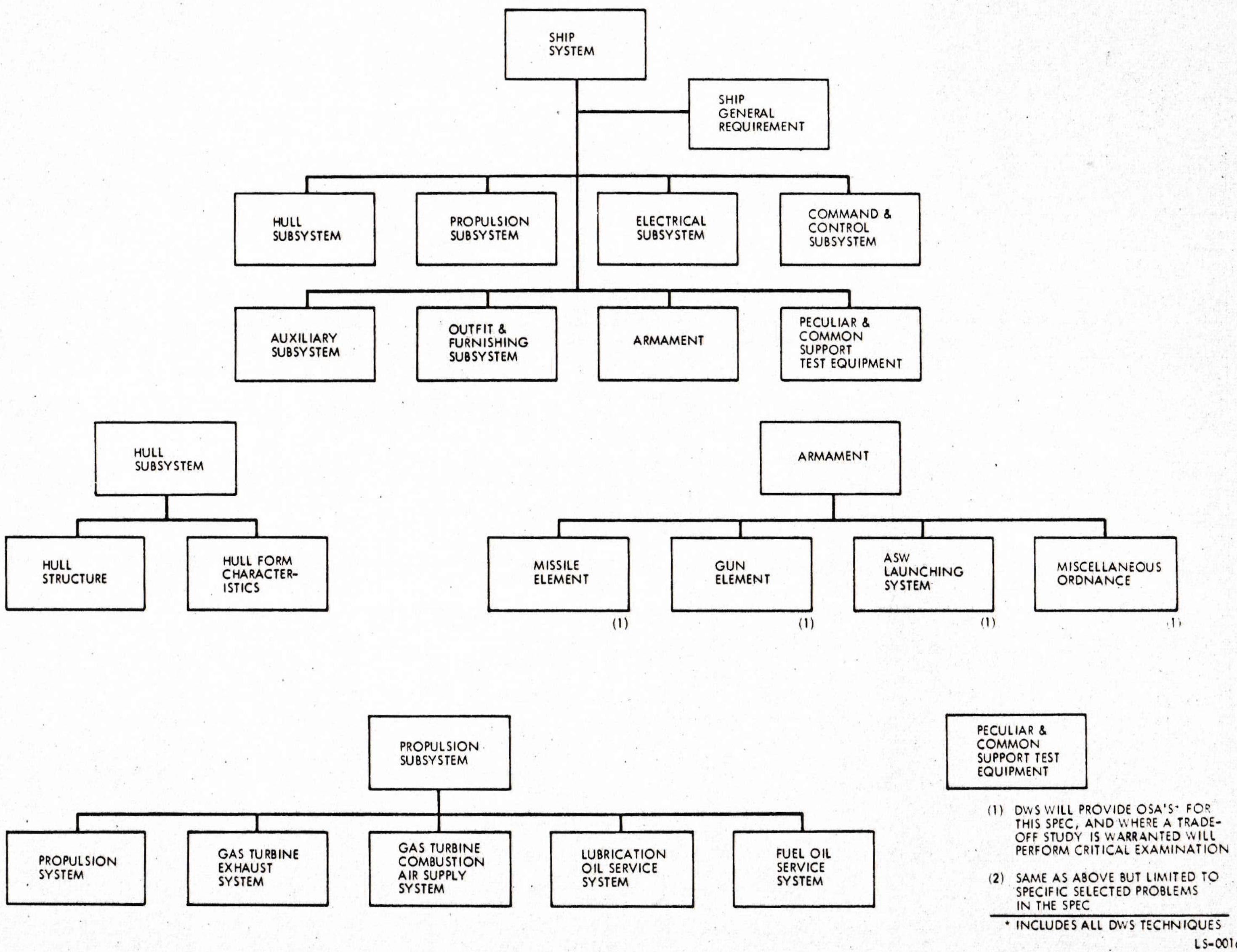
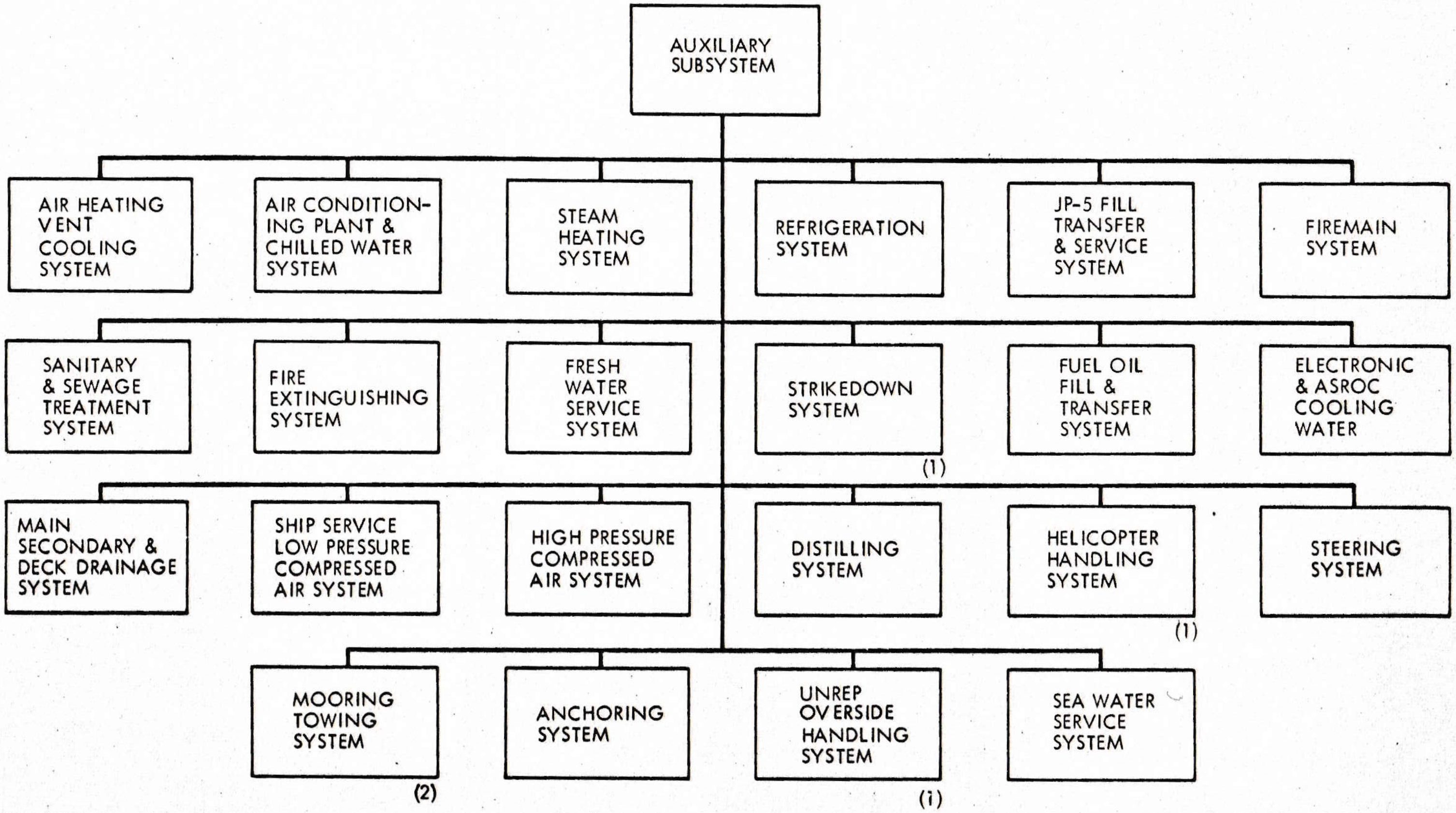


Figure 3-3 DWS Specification Relationships (Sheet 1 of 4)



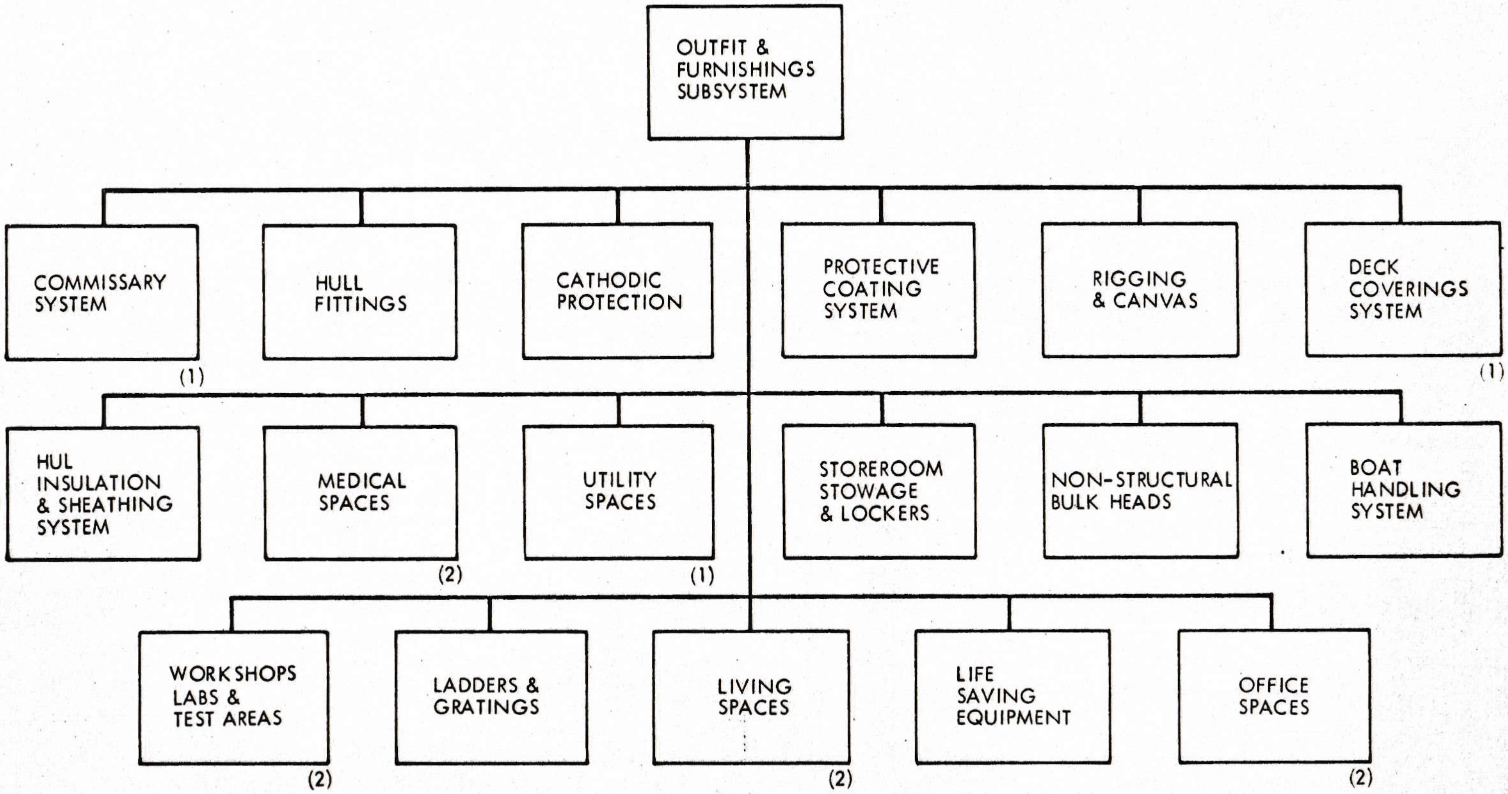
(1) DWS WILL PROVIDE OSA'S* FOR THIS SPEC, AND WHERE A TRADE-OFF STUDY IS WARRANTED WILL PERFORM CRITICAL EXAMINATION

(2) SAME AS ABOVE BUT LIMITED TO SPECIFIC SELECTED PROBLEMS IN THE SPEC

* INCLUDES ALL DWS TECHNIQUES

LS-0017

Figure 3-3 DWS Specification Relationships (Sheet 2 of 4)



(1) DWS WILL PROVIDE OSA'S* FOR THIS SPEC, AND WHERE A TRADE-OFF STUDY IS WARRANTED WILL PERFORM CRITICAL EXAMINATION

(2) SAME AS ABOVE BUT LIMITED TO SPECIFIC SELECTED PROBLEMS IN THE SPEC

*INCLUDES ALL DWS TECHNIQUES

LS-0015

Figure 3-3 DWS Specification Relationships (Sheet 3 of 4)

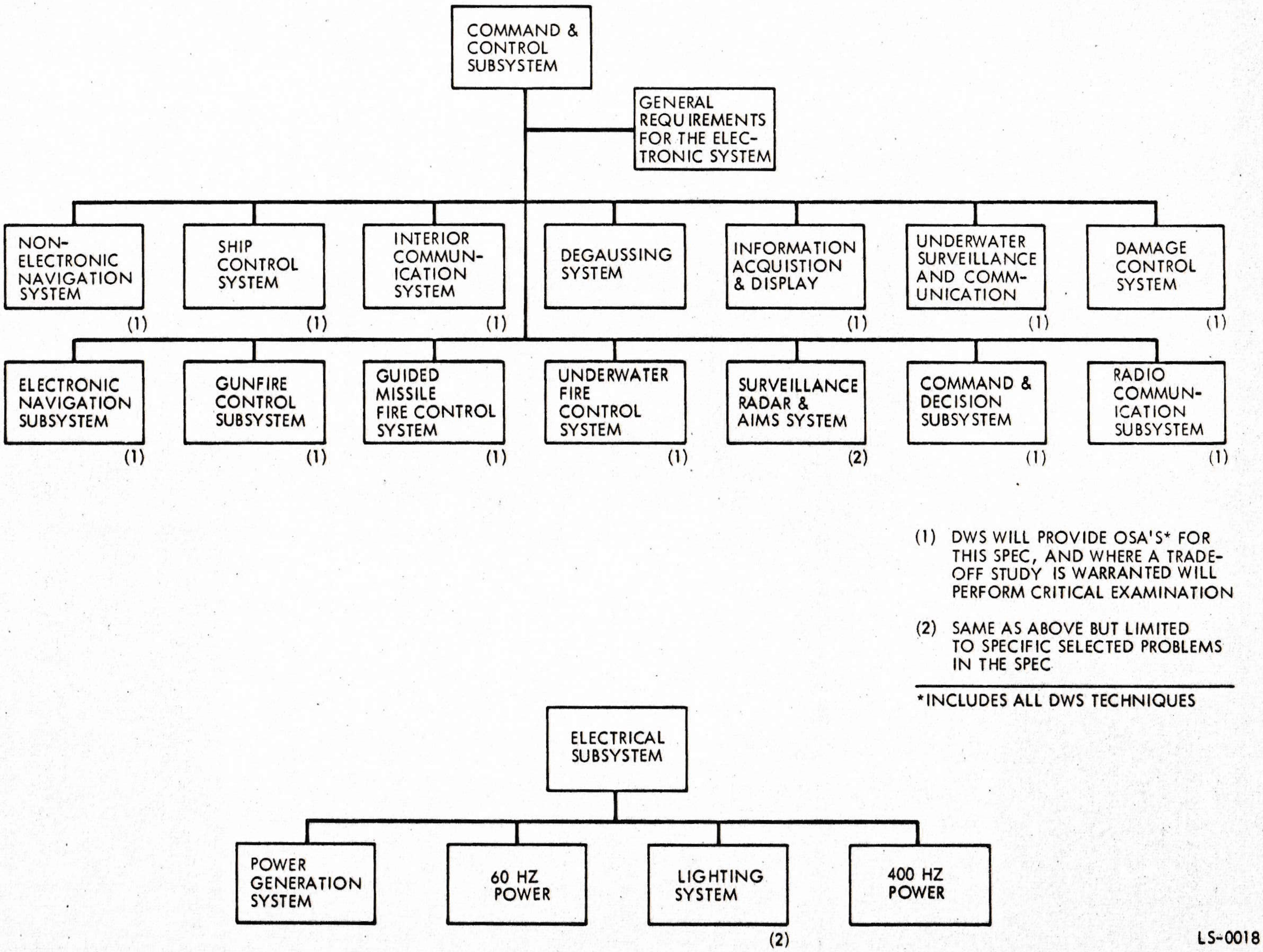


Figure 3-3 DWS Specification Relationships (Sheet 4 of 4)

documents, organized in accordance with military specification format and transmitted to the engineering design organization responsible for specification content.

3.5 NAVY DWS ORGANIZATIONAL ELEMENTS

The responsibility for initiating and coordinating all DWS is vested with NAVSHIPS/NAVSEC - Manning/DWS/Human Factors, NAVSEC Code 6102B.

To initiate a project, the Ship Acquisition Project Manager (SHAPM) will designate task responsibility to a NAVSEC Project Coordinator/Ship Design Manager who will in turn assign overall task responsibility to NAVSEC Code 6102B for DWS, Human Factors Engineering and Manning (as indicated in NAVSECINST 5430.12).

The subparagraphs that follow provide details of the internal responsibilities for Code 6102B and the interactions with other Navy elements.

3.5.1 Responsibilities

Once tasked by the project coordinator, Code 6102B will interact with other Navy agencies to develop the following:

- Perform and/or Coordinate DWS analysis
- Provide Functional Analysis
- Identify High Manpower Usage Areas
- Provide Initial Manning Estimates
- Participate in Producing Plans and Schedules
- Monitor Human Factors Efforts
- Producing Preliminary Ships Manning Document
- Assessing Manning Impacts
- Integration of all DWS and OSB's
- Provide DWS Liaison

3.5.2 DWS Coordination

Thru the Project Coordinator and SHAPM, SEC 6102B, Code 6102B will coordinate all DWS inputs shown in Figure 3-1 from other SEC codes, NAVSHIPS, and SYSCOMS to develop SMD and OSB.

BIBLIOGRAPHY

- NAVSHIPS 0900-060-0010 Ship Life Cycle Management Manual (Acquisition Phase) Policy and Guidance Volume I March 1971
- NAVSHIPS 0900-005-1040 Problem Data Manual for Design Work Study: Ship Improvement
- NAVSHIPS 0900-005-1020 Problems and Exercises, Design Work Study
- NAVSHIPS 0900-005-1030 Problem Data Manual for Design Work Study Courses, Concept and Contract Design and Program Management
- SECNAVINST 5000. 1 SO-1 System Acquisition in the Department of the Navy 13 March 1972
- OPNAVINST 5300. 3 OP-100 Development and Review of Enlisted Manpower Requirements in Naval Ships, 2 August 1967
- OPNAV 10P-23 Guide to Preparation of Ship Manning Document, Vol. I, 3 Feb. 1971
- OPNAV 12P4 Guide to Preparation of Ship Manning Documents, Vol. II 18 August 1971
- NAVSHIPSINST 5200. 17 Shipborne System/Equipment Acquisition Manual (SS/EAM) 12 October 1971
- CNMINST 5300. 8 Development and Review of Enlisted Manpower Requirements in Naval Ships
- MIL-H-46855 Military Specification, Human Engineering Requirements for Military Systems, Equipment and Facilities, 29 March 1968
- MIL-STD-1472A Military Standard, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, 15 May 1970
- MIL-M-23313 Maintainability Requirements for Shipboard Electronic Equipment and Systems
- MIL-O-24312A (Ships) Military Specification Operational Stations Book (OSB) 30 June 1969
- MIL-M-23313 Maintainability Requirements for Shipboard Electronic Equipment and Systems
- Technical Manual for Design Work Study (NAVSHIPS 0900-005-1010 02 Manual of Work Study Technology, Stanwick Corp.)

BIBLIOGRAPHY (Continued)

NAVSEC 90-20/1B, System Sequence Diagrams (OSD)

NAVSEC 90-20/2, Critical Examination Sheet I

NAVSEC 90-20/2A, Critical Examination Sheet II

NAVSEC 90-20/2B, Critical Examination Sheet III

NAVSEC 90-20/2C, Design Worksheet

NAVSEC 90-20/3, Manning Chart

NAVSEC 90-20/3A, Manning Examination Chart

NAVSECINST 5430. 12, NAVSEC Shipboard Manning Requirement Development

LIST OF ACRONYMS

CE Sheet	Critical Examination Sheet
CEB	CNO Executive Board
CD	Concept Definition
CDRL	Contract Data Requirements List
CMC	Commandant of the Marine Corps
CNO	Chief of Naval Operations
CONREP	Connected Replenishment
CV	Concept Validation
DCP	Development Concept Paper
DSARC	Defense System Acquisition Review Council
DWS	Design Work Study
ECP	Engineering Change Proposal
FPC	Flow Process Chart
FSD	Functional Sequence Diagram
MAC	Multiple Activity Chart
MEA	Maintenance Engineering Analysis Record
MIP	Maintenance Index Page
MRC	Maintenance Requirements Card
NAVSEC	Naval Ship Engineering Center
NAVSHIPS	Naval Ship Systems Command
OSB	Operational Stations Book
OSD	Office of the Secretary of Defense
OSD	Operational Sequence Diagram
OPC	Outline Process Chart
PERT	Program Evaluation and Review Technique
PFM	Plans for Maintenance
PI	Program Initiation
PMS	Planned Maintenance System
R&D	Research and Development
R/M/A	Reliability/Maintainability/Availability
RT	Reaction Time
SCN	Specification Change Notice
SECDEF	Secretary of Defense
SECNAVINST	Secretary of Navy Instructions
SHAPM	Ship Acquisition Project Manager
SMD	Ships Manning Document
T&E	Test and Evaluation
UNREP	Underway Replenishment
VERTREP	Vertical Replenishment